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Volume 5 | Technical Appendices

CFA23 | Balsall Common and Hampton-in-Arden

River modelling of the River Blythe and Bayley's Brook technical report (WR-004-017)

Water resources

November 2013

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Appendix WR-004-017

Environmental topic:	Water resources and flood risk assessment	WR
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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise a number of parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 A number of specific appendices for each community forum area are also provided. For the Balsall Common and Hampton-in-Arden (CFA23) and Birmingham Interchange and Chelmsley Wood area (CFA24) these are:

- water resources assessments (Volume 5: Appendix WR-002-023 and WR-002-024);
- flood risk assessments (Volume 5: Appendix WR-003-023 and WR-003-024)
- a hydrology report for the River Blythe and associated tributaries (Volume 5: Appendix WR-004-016);
- a hydraulic modelling report for the River Blythe and Bayleys Brook at Balsall Common viaduct (this Appendix); and
- a hydraulic modelling report for the for Bayleys Brook (at Marsh Farm and Lavender Hall Lane), the River Blythe Bypass, Shadow Brook and Hollywell Brook (Volume 5: Appendix WR-004-018).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5 water resources map book.

1.2 Scope of this assessment.

1.2.1 Hydraulic models were constructed to enable an assessment of a) the baseline "as-is" condition and b) with the Proposed Scheme included, to allow for review of impacts on flood risk. In order to assess the scheme the following has been undertaken:

- model a range of return periods from 50% AEP to 1% AEP plus climate change for the pre- and post-development situations to ascertain peak flood levels and flood extent;
- develop mitigation options for post-development; and
- inform land required for the scheme.

1.3 Location

1.3.1 This report focuses on CFA23 Balsall Common and Hampton-in-Arden and Birmingham Interchange and Chelmsley Wood area (CFA24). The areas of consideration are shown in Figure 1 and Figure 2.

Figure 1: Balsall Common and Hampton-in-Arden

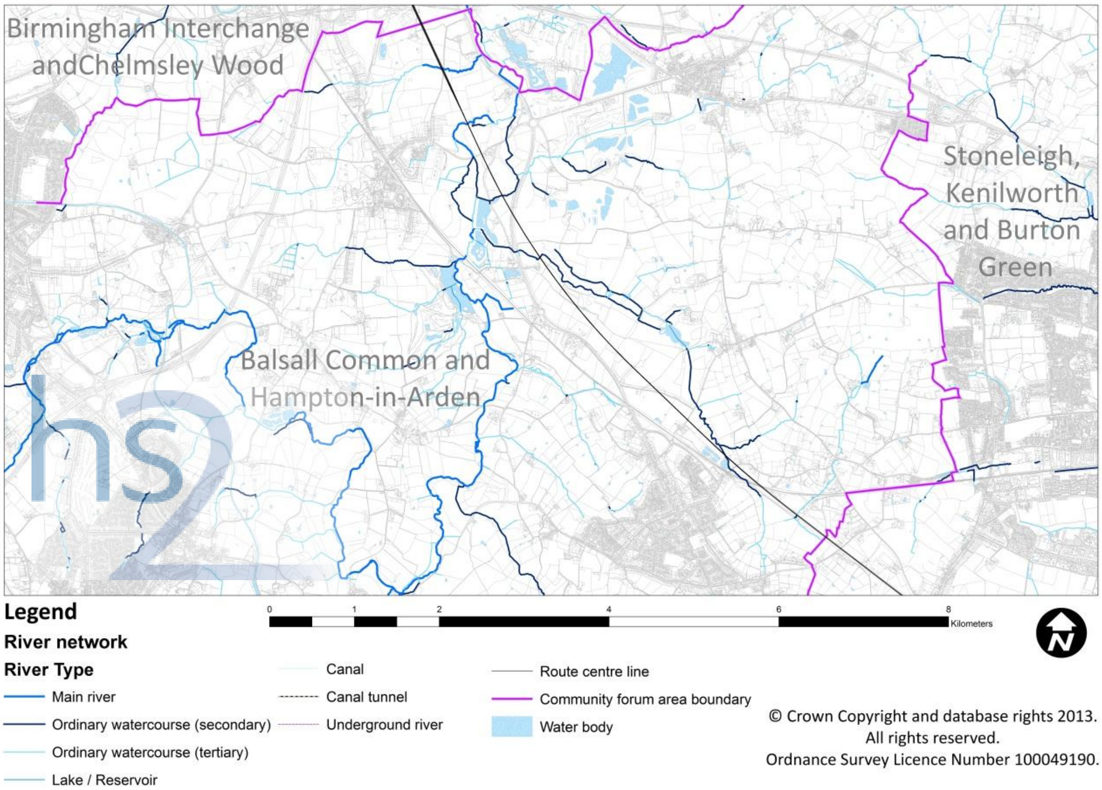
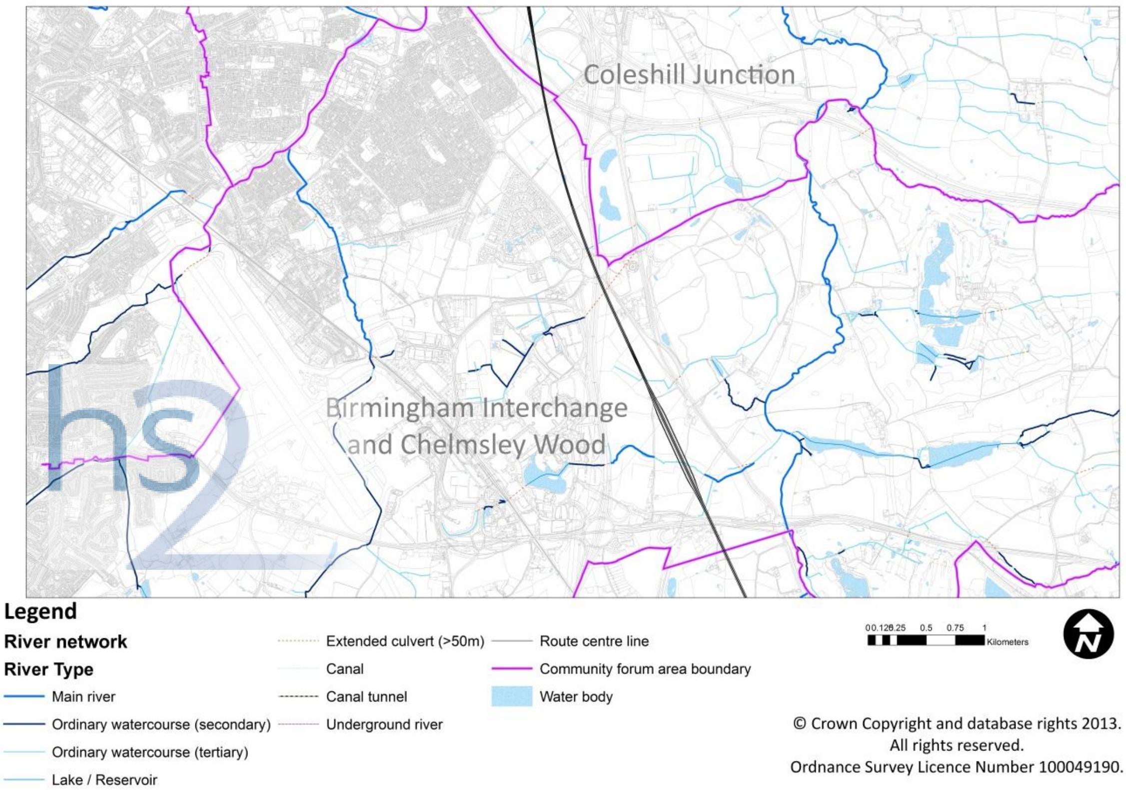


Figure 2: Birmingham Interchange and Chelmsley Wood



2 Overview

2.1.1 The impact on flood risk due to the Proposed Scheme has been reviewed and options to mitigate increase in flood risk have been developed. The Proposed Scheme includes the main line, additional bridges and diversions of rivers and is detailed in the flood risk assessments (FRAs) (Volume 5: Appendices WR-003-023 and WR-003-024).

2.1.2 This report outlines the hydraulic modelling of two watercourse crossings within the CFA23 boundary of the Proposed Scheme; namely the River Blythe and the Bayleys Brook, a tributary to the River Blythe.

2.1.3 The modelling exercise described in the following sections was prepared to inform the site specific flood risk assessment for the Proposed Scheme's structures - River Blythe viaduct and Balsall Common viaduct, both in rural Warwickshire. This report's aims are to describe the bespoke hydraulic models developed to quantify the impacts of the proposed infrastructure on the River Blythe's and Bayleys Brook's current (baseline) and post-development flood risks.

2.1.4 The hydraulic models developed cover local extents of watercourses around these structures:

- River Blythe viaduct: the River Blythe between Siden Hill Wood and Diddington Hall, with a total extension of 3.2km around the proposed viaduct (OS reference SP214817) with a contributing catchment area of 131km²; and
- Balsall Common viaduct: a 0.8km section of the Bayleys Brook with its upstream end located on the west side of Truggist Lane with a contributing catchment area of 157km².

2.1.5 Due to their specific out-of-bank flow patterns, flood events for both watercourses have been modelled using purely 2D models. The proposed models represent the watercourses' main channels and rural floodplains with a level of detail deemed sufficient for this project to establish extreme water levels and flood flow paths throughout the areas of interest for pre and post-development scenarios and a range of return periods. The limitations to the modelling which are described in Sections 0 and 0.

2.1.6 Neither watercourse has any flow monitoring within the study area; nor has any previous detailed modelling been undertaken. Outputs from the Environment Agency's indicative flood mapping were provided, together with the Flood Zones 2 and 3 extents.

2.2 Problem definition

2.2.1 Currently the Proposed Scheme includes crossings of both the River Blythe and Bayleys Brook. A number of infrastructure changes which will interact with the river system include:

- main line track on embankment and viaduct;
- a river realignment on Bayleys Brook at Balsall Common viaduct; and
- viaduct crossings at the River Blythe and Bayleys Brook.

2.2.2 To understand the flood risk, and to inform mitigation measures, it was apparent that hydraulic modelling would be required.

3 Hydrology

3.1.1 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed crossing point of the Proposed Scheme. Full details of the calculation process can be found in Volume 5: Appendix WR-004-016.

4 Common modelling approach & data sources

4.1.1 Due to their specific out-of-bank flow patterns and, in the case of Bayleys Brook, the high skew angle of crossing by the Proposed Scheme infrastructure, fully 2D modelling using TUFLOW was considered the most appropriate method of modelling the two watercourses, particularly given the complete absence of channel survey information. Typically, 1D models are used to represent the in-bank portion of watercourses, with 2D models used to represent out-of-bank flows. However, in this case, relatively high resolution 2D model grids were used to characterize the watercourses' main channels and rural floodplains. Representing the main channel within a 2D model instead of a 1D model can cause the capacity of the main channel to be over or under-estimated, particularly at low flows, and as a result this can misrepresent the onset and level of flooding (refer to Sections 5.1 and 6.1 which give an overview of the modelling approach).

4.1.2 This choice of model allows the representation of the main features present in the area of interest and the estimation of their effects on extreme water levels and flood flow paths. The features of interest are:

- water levels and flows along the watercourses, taking into account approximate channel dimensions and assumed roughness;
- water levels and flow paths across the watercourses' floodplains, taking into account ground levels, land uses and obstructions to flow (e.g. road embankments, buildings, etc.);
- attenuation of peak flows along the river systems; and
- impact on water levels and flood flow paths of the Proposed Scheme (refer to Sections 5.4 and 6.3).

4.1.3 The 2D models representing the watercourses' main channels and rural floodplains for pre and post-development scenarios were simulated for unsteady flow hydrographs for a range of storm events with return periods of 50%, 10%, 5%, 2%, 1.33%, 1% and 0.1% AEP. The 1% AEP event with 20% increase in flows to account for climate change has also been simulated.

4.1.4 Both in-bank and out-of-bank flows were represented in 2D models developed using the LiDAR (Light Detection and Ranging) ground elevation data and Ordnance Survey MasterMap data described below.

4.2 Input data

4.2.1 A number of data sources were referenced as part of these works and are outlined as follows:

- topographic survey (200mm grid resolution laser interferometry detection and ranging (LiDAR) survey, in digital terrain model and digital surface model format) and associated aerial photography;
- Ordnance Survey MasterMap (Ordnance Survey, 2012) - MasterMap (vector) data features in the MasterMap data for the entire area of interest were last verified between 2001 and 2012;

- aerial imagery (Geostore, 2012) provided at 25cm resolution and of varying collection dates prior to 2012;
- Environment Agency flood map data -Flood Zone 2, Flood Zone 3[1], defences, storage areas;
- historic flood extents[2];: historic flood extents were provided for the 1992 and 2007 flood events; and
- channel and structure survey: no channel survey or survey of hydraulic structures has been undertaken. Site visits were made to obtain an overview of key features such as roughness and notable features. Where there were existing hydraulic structures, an estimation of sizing was also undertaken.

[1] Environment Agency, (2012), Flood zone mapping GIS layer

[2] Environment Agency, (2012), Midlands Historical 1992 and 2007 flood event GIS layers

5 Bayleys Brook at Berkswell

5.1 Modelling overview

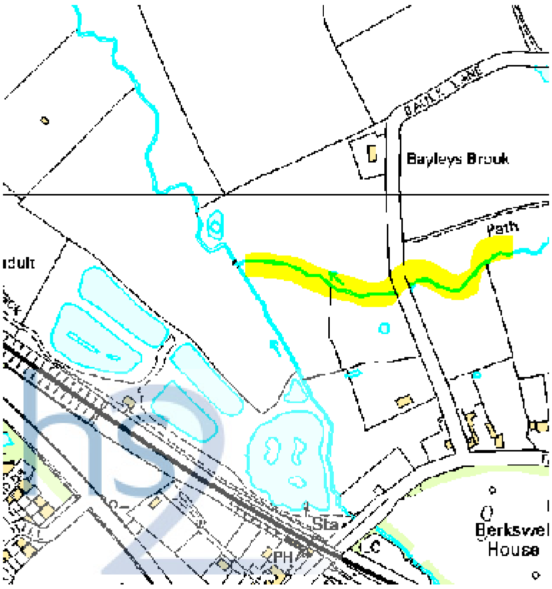
5.1.1 This hydraulic model covers a 0.8km section of the Bayleys Brook around the Balsall Common viaduct with the upstream end located on the downstream side of Truggist Lane. The model is fully 2D and is based on a regular grid with a resolution of 2m. The channel bed has been estimated as being 3-4m wide with the top of channel being 4-6m wide. To improve the definition of the channel in the model, the course of the channel has been defined and the bed level has been assumed to be 0.3m below the level indicated by the LiDAR data. The ground elevations in the model were updated using the most recent 0.25m LiDAR data, which was flown in 2012. Ground levels within the modelled areas range between 100.0 and 122.0m AOD.

5.1.2 The model covers a total area of 16 hectares along the 0.8km reach, which extends sufficiently far to contain the flood extents of all modelled events (with AEPs up to 0.1%).

5.1.3 Roughness values are specified in the TUFLOW model spatially and assigned a Manning's n roughness coefficient. The model uses only two values for roughness, one for the watercourse (0.030) and one for rural land (0.050).

5.1.4 The model applies a single flow-time boundary at the upstream end of the modelled reach, just downstream of Truggist Lane. To provide a conservative estimation of flood risk, no allowance has been made for attenuation of flows upstream of Truggist Lane. It has also been assumed that Truggist Lane does not overtop and that the culvert conveys all flood flows. There is a tributary downstream of the proposed route (highlighted in yellow in Figure 3); the flows from this have been added to the upstream boundary and not as a separate inflow, which is a conservative assumption in this case.

Figure 3: Tributary to Bayleys Brook (highlighted in yellow)



5.1.5 Inflow hydrographs were generated for a duration of 6 hours on Bayleys Brook which was based on the recommendations from the revitalised flood estimation handbook rainfall runoff method, ReFH.

5.1.6 The Bayleys Brook model used the average bed slope over the last 100m of the modelled reach, which was found to be 1 in 250 (0.004m/m).

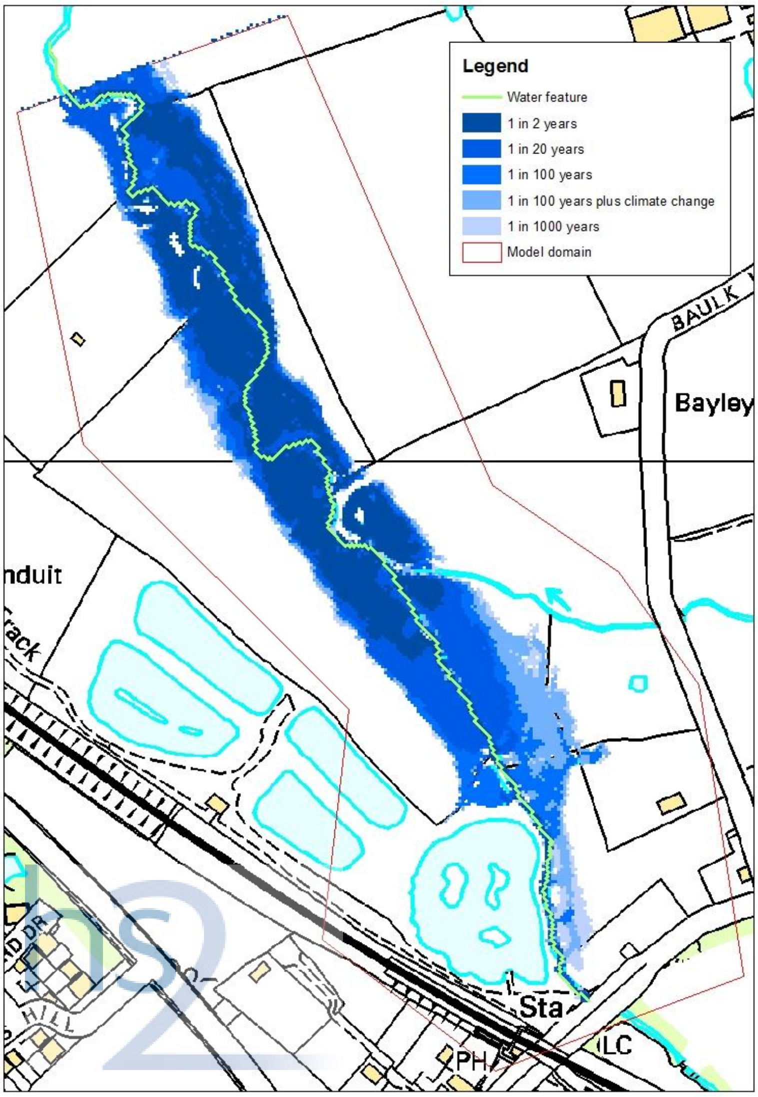
5.1.7 The recommended/default values of runtime parameters were used in all model simulations. A time step of 0.5s was used in the model simulations, which is within the recommended range for a 2m resolution model.

5.1.8 Mass balance checks were undertaken to ensure the models adequately conserve volume, i.e. do not gain or lose large volumes of water during model simulations. Mass errors are all below the typical threshold of 1%, indicating healthy/stable model.

5.2 Baseline model results

5.2.1 The baseline flood extents for key return periods are shown in Figure 4.

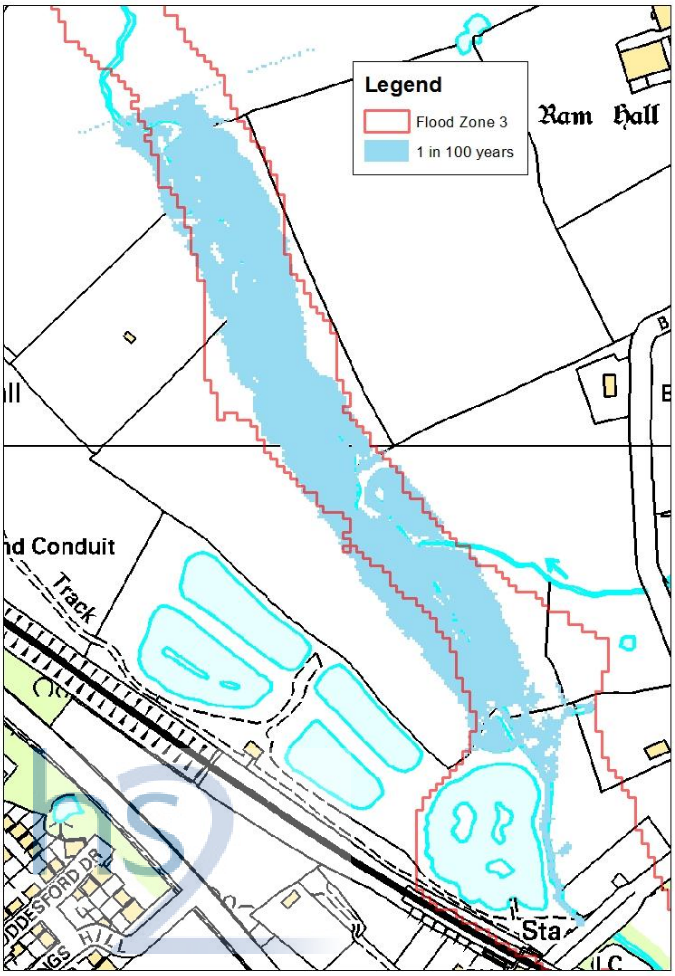
Figure 4: Bayleys Brook baseline modelling results for key AEPs (Volume 5: Map book WR05 and WR06)



5.3 Comparison with national flood risk assessment mapping

5.3.1 The results in general compare favourably to the coarse national flood risk assessment mapping (NFRAM) as shown in Figure 5 for the 1% AEP event. The notable exception is the lack of flooding within the pond to the west, and a smaller extent to the east of Bayleys Brook. This is due to significant differences in the quality of the digital terrain models used, with the NFRAM using lower quality data (Figure 6 and Figure 7).

Figure 5: Comparison of modelled 1% AEP event (blue) and flood zone 3 (red)



5.3.2 The DTM used to create the NFRAM was supplied and shown in Figure 6.

Figure 6: Digital terrain model (DTM) used in NFRAM

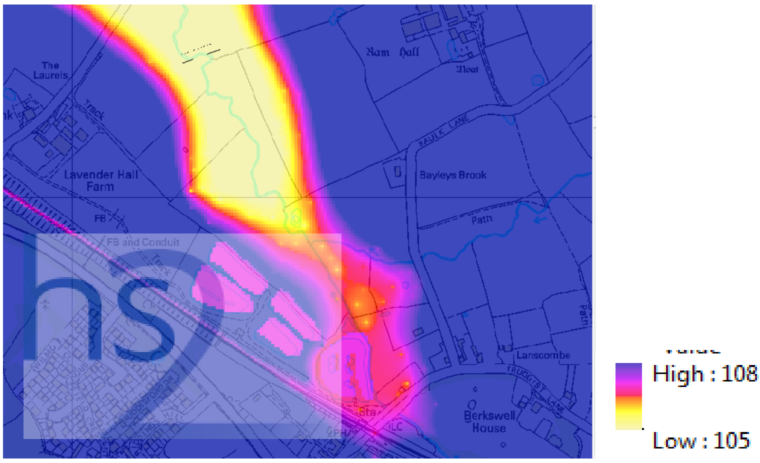


Figure 7: 0.25m LiDAR DTM used in Arup, 2013 modelling

5.3.3 Comparing the two DTMs, which have the same colour scheme in the above figures, it can be seen that there are substantial differences. The 0.25m LiDAR identifies a high ridge running along the eastern extent of the pond, and there is a high ridge on the eastern extent of the brook. Given the differences in quality of data, it is thought that the updated modelling gives improved confidence in flood extents and flood water levels.

5.3.4 It is recommended that further consideration is given to the culvert under Truggist Lane to assess its capacity and the likelihood of flows bypassing the culvert during flood events. However, the 0.25m LiDAR indicates the lowest level of Truggist Lane at the eastern extent is 107.1m, which is 0.2m above the 0.1% AEP level predicted by the model immediately downstream but the upstream level will be higher. At present, the model has been developed for downstream of Truggist Lane, and the inflow for the whole catchment has been applied here. Although the lane may overtop from upstream, it is unlikely that the Proposed Scheme will be impacted as the flow reaching it will be lower than currently modelled due to attenuation upstream of Truggist Lane. If Truggist Lane were to overtop, it is unlikely to effect the baseline/post-development comparative assessment undertaken herein. It is recommended that when detailed survey becomes available, the impact of Truggist Lane on flood risk to the Proposed Scheme is further reviewed.

Implications for the Proposed Scheme

5.3.5 Balsall Common viaduct will be 275m long and will be divided into a number of 25m spans to span from Truggist Lane to Bayleys Brook. The proposed viaduct includes piers within the floodplain, and a small local diversion of the Bayleys Brook will be required to accommodate these. On the left bank of Bayleys Brook, the route is proposed to run on embankment on the upstream side, and a combination of embankment and vertical retaining wall on the downstream side collectively known as Lavender Hall embankment.

5.4 Post-development modelling

5.4.1 Post-development models have been developed from the baseline models and have incorporated the Proposed Scheme infrastructure as follows:

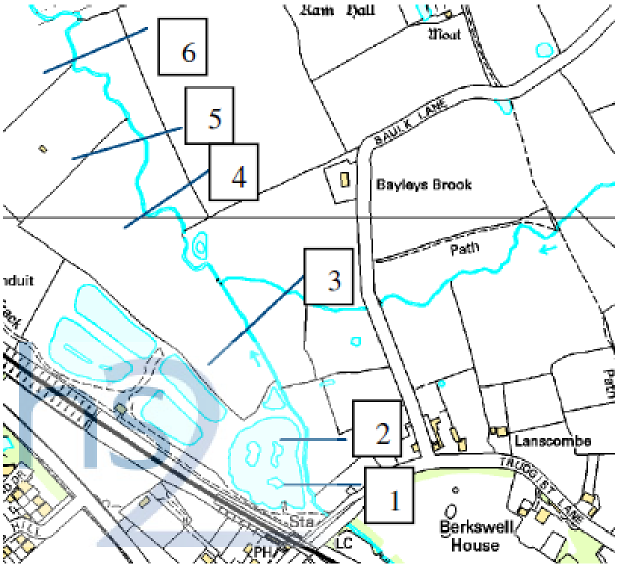
- earthworks: these were represented in the TUFLOW model using proposed earthworks ground levels provided in the scheme design drawings;
- viaduct: the small loss of floodplain volume due to the proposed viaduct piers were represented in the TUFLOW model by raising ground levels in these grid cells. It was assumed that the piers were 2m wide by 15m long. The openings were included as constrictions in the blockage sensitivity analyses; and
- river diversion on Bayleys Brook: this was included in the TUFLOW model by infilling the existing channel and linearly interpolating the levels along the new route based on upstream and downstream bank and bed levels.

Post-development modelling results

5.4.2 A post-development scenario model has been developed from the baseline model to reflect the Proposed Scheme infrastructure, which includes a viaduct (only three spans were modelled as the floodplain did not extend as far as Truggist Lane), embankments and vertical retaining wall, with a varying soffit of between ~109 and 113m AOD. The Proposed Scheme is embanked as it approaches the viaduct over Baileys Brook. This has been included in the model by modifying the ground levels at the embankment. The piers of the viaduct have been represented using z-shapes, which are set to a sufficiently high elevation so prevent any flow through the footprint of the piers. The viaduct itself has been modelled using a layered flow constriction shape file, this allows for the accurate assessment of blockage, and allows openings, deck and railings to be assessed separately. The spacing between piers is 25m, with a deck of approximately 3m thickness. The brook requires a slight diversion (Volume 2: Map book CT-06) to allow it to flow between the viaduct piers, this has also been included by modifying the ground elevations to represent the new channel. The current channel alignment at the diversion has been removed from the model using a z-shape and the materials layer has been updated to remove the old channel and include the diversion.

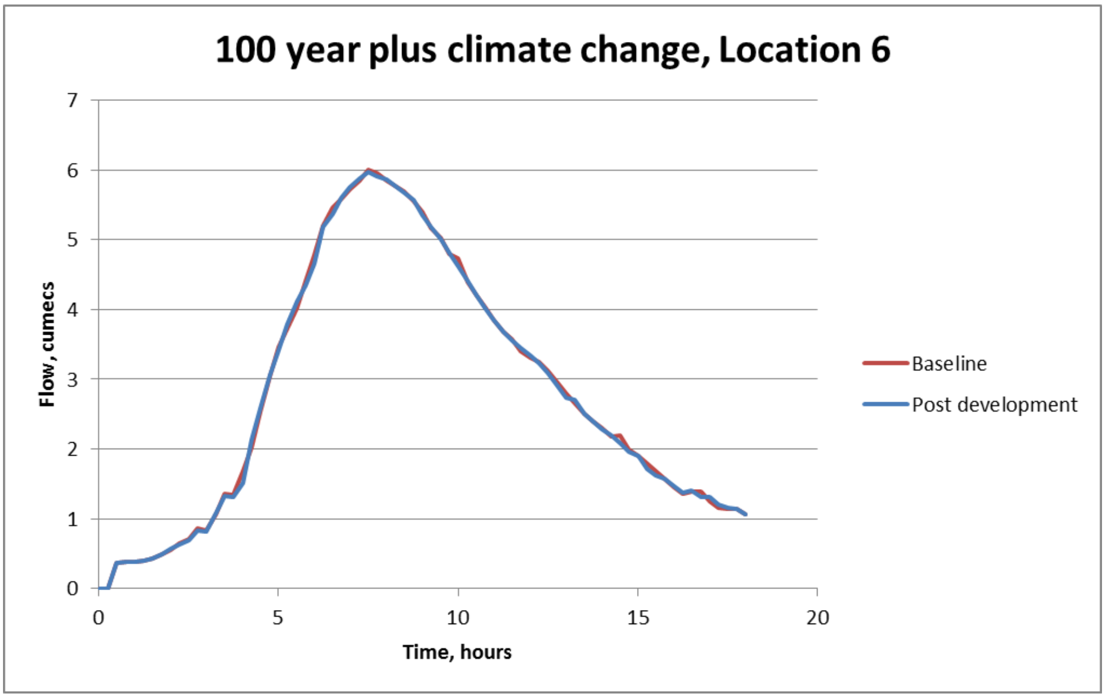
5.4.3 In order to establish the impact of the Proposed Scheme on flood risk at the site, the change in flow hydrograph and change in flood depth have been examined for all return periods. Six locations have been chosen to examine the hydrograph changes and are shown in Figure 8. These have been orientated in the main flow direction not in the direction of the viaduct and have been numbered sequentially 1-6 from upstream to downstream.

Figure 8: Hydrograph extraction points



5.4.4 Typically there is no change in the downstream hydrograph, but for the 5% AEP and 2% AEP events, there is a small increase in downstream peak flow. For the 5% AEP event, the increase is <0.1m³/s (2.8%) and in the 2% AEP event it is 0.03m³/s (less than 1%). At present, the model does not include replacement floodplain storage which is being provided on the left hand floodplain adjacent to the embankment to mitigate lost volume due to the embankment footprint within the floodplain.

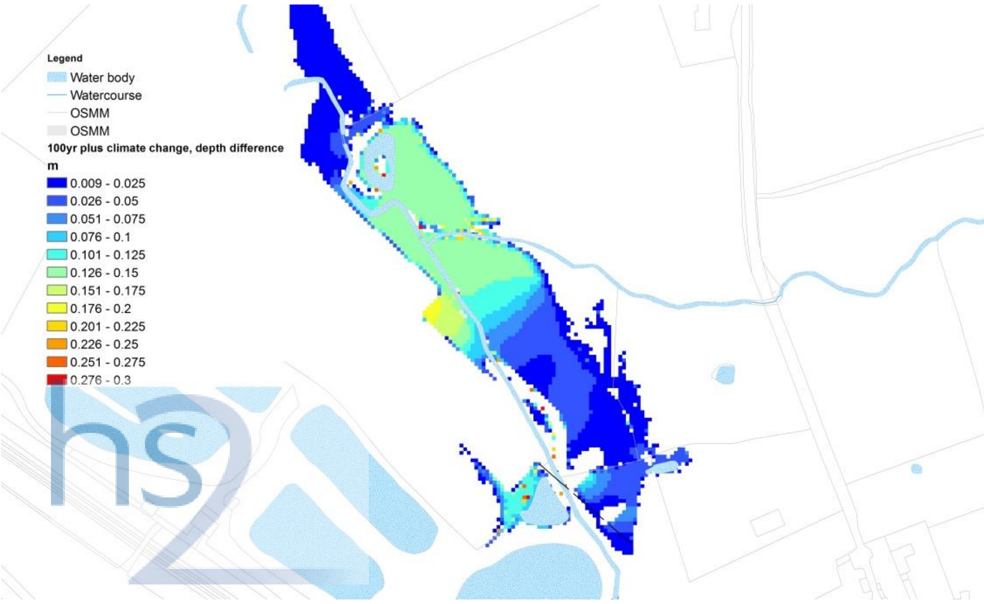
Figure 9: 1% AEP plus climate change hydrograph downstream



5.4.5 The 1% AEP plus climate change flood event exhibits the largest differences in flood levels between baseline and post development. From Figure 10, it can be seen that differences in flood levels are up to 150mm, which occur downstream (north-east) of the embankment. There are local increases in flood depths of approximately 250mm at the western embankment on the upstream side due to the displacement of flooding, but this is over a very localised area. Differences greater than 300mm have been removed from Figure 10 as these correspond to the river diversion channel and are do not represent increase in floodplain depths. At the downstream extent of the model, flood levels return to baseline levels.

5.4.6 Improved topographical survey data would allow for better representation of the existing channel, and therefore allow for improved design of the proposed diversion.

Figure 10: 1% AEP plus climate change flood level difference between baseline and post development (negative values removed & those greater than 300mm removed)



5.4.7 The flood extent for the 1% AEP plus climate change event is largely unchanged between post development and baseline. There is a very small increase on the eastern downstream floodplain (see Figure 11), which is due to the increased flood levels in this vicinity. There is also an increase in extent to the upstream side of the western embankment where floodplain is displaced by the embankment.

Figure 11: 1% AEP plus climate change flood extent for baseline (red) and post development (blue)

5.5 Sensitivity testing

Overview

5.5.1 Given the absence of calibration data, surveyed flood levels or historic flood outlines for the modelled reaches of the Bayleys Brook, a range of sensitivity tests were undertaken for the most critical assumptions within the baseline model. These are:

- roughness coefficients (increasing and decreasing Manning's roughness by 20%) for the 1% AEP event;
- downstream boundary condition for the 1% AEP event; and
- blockage analysis of the Balsall Common viaduct (blocked by 2%) and downstream structures (10%) for the 0.1% AEP event.

Roughness coefficients

5.5.2 The baseline models' sensitivity to roughness coefficients was assessed by considering ±20% variations on the adopted Manning's 'n' roughness values.

5.5.3 Increasing Manning's roughness by 20% resulted in typical change in baseline water level of less than ±40mm, but there are a few local locations which exhibit larger differences up to a maximum of 130mm (Figure 12). This is isolated to the upper reaches of the brook and to a small area on to the north east.

5.5.4 The flood extent remains largely unchanged, with the exception of the area to the north east which increases in extent (Figure 13).

Figure 12: Change in depth between baseline and increasing 'n' by 20% for 1% AEP

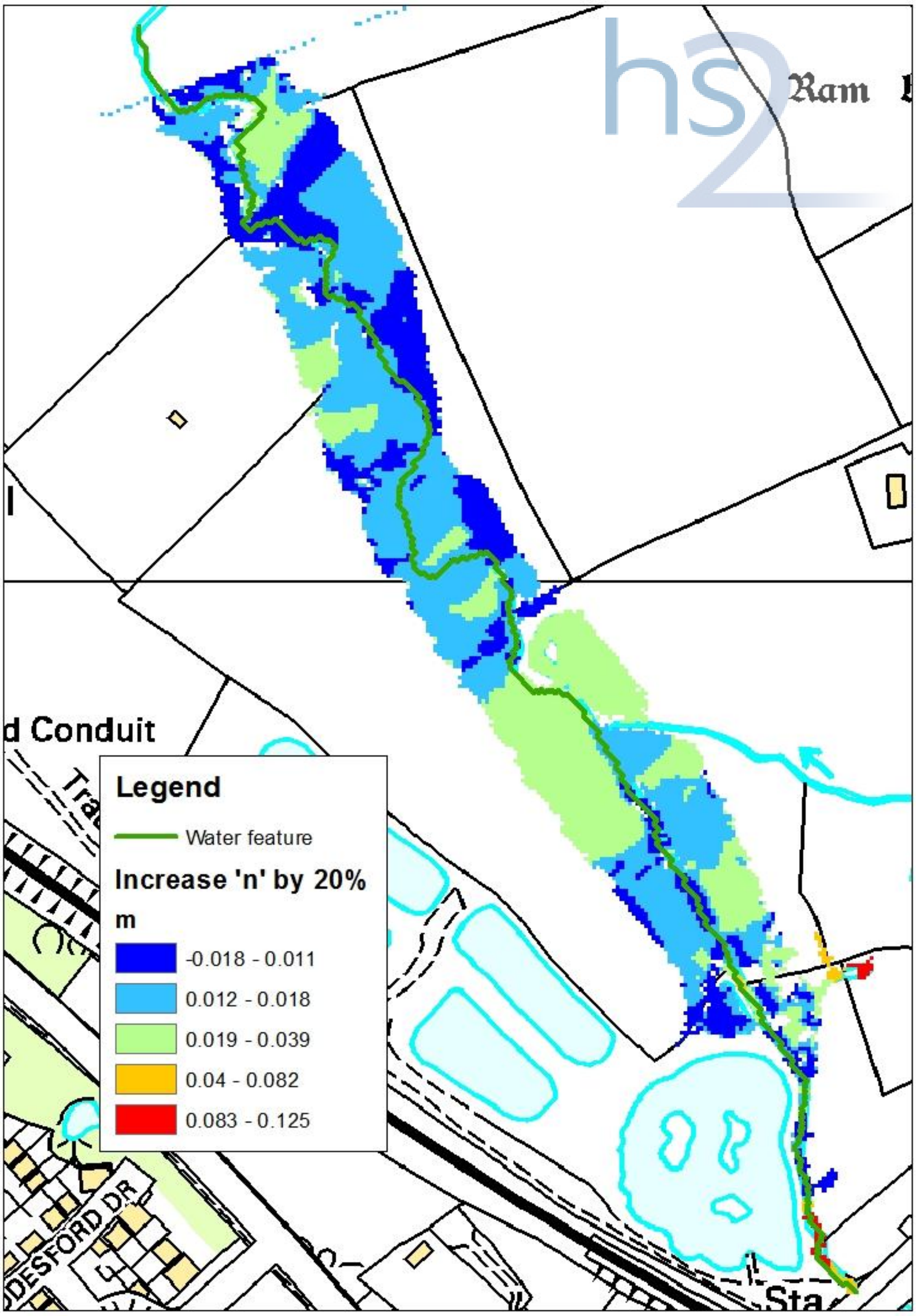
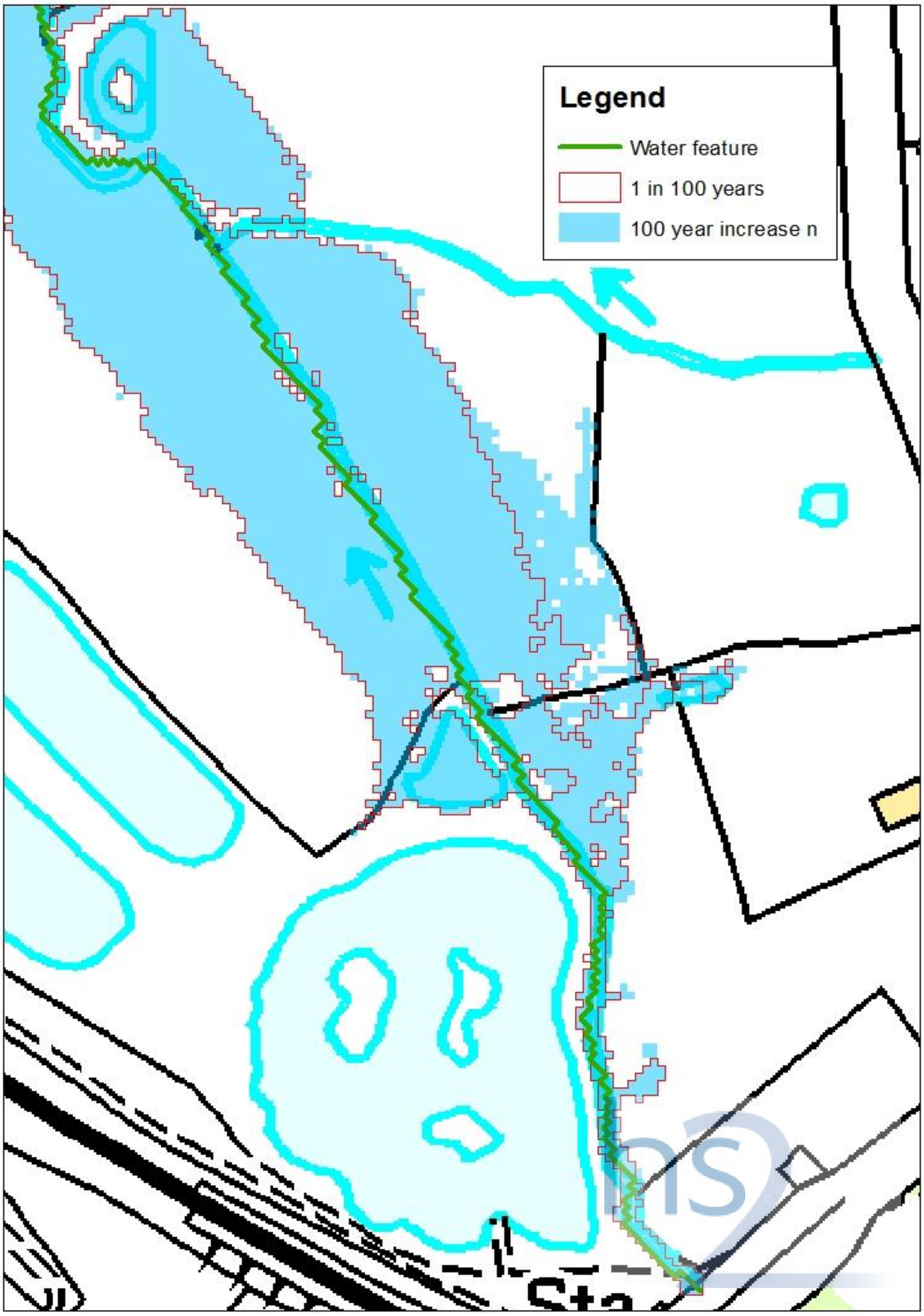
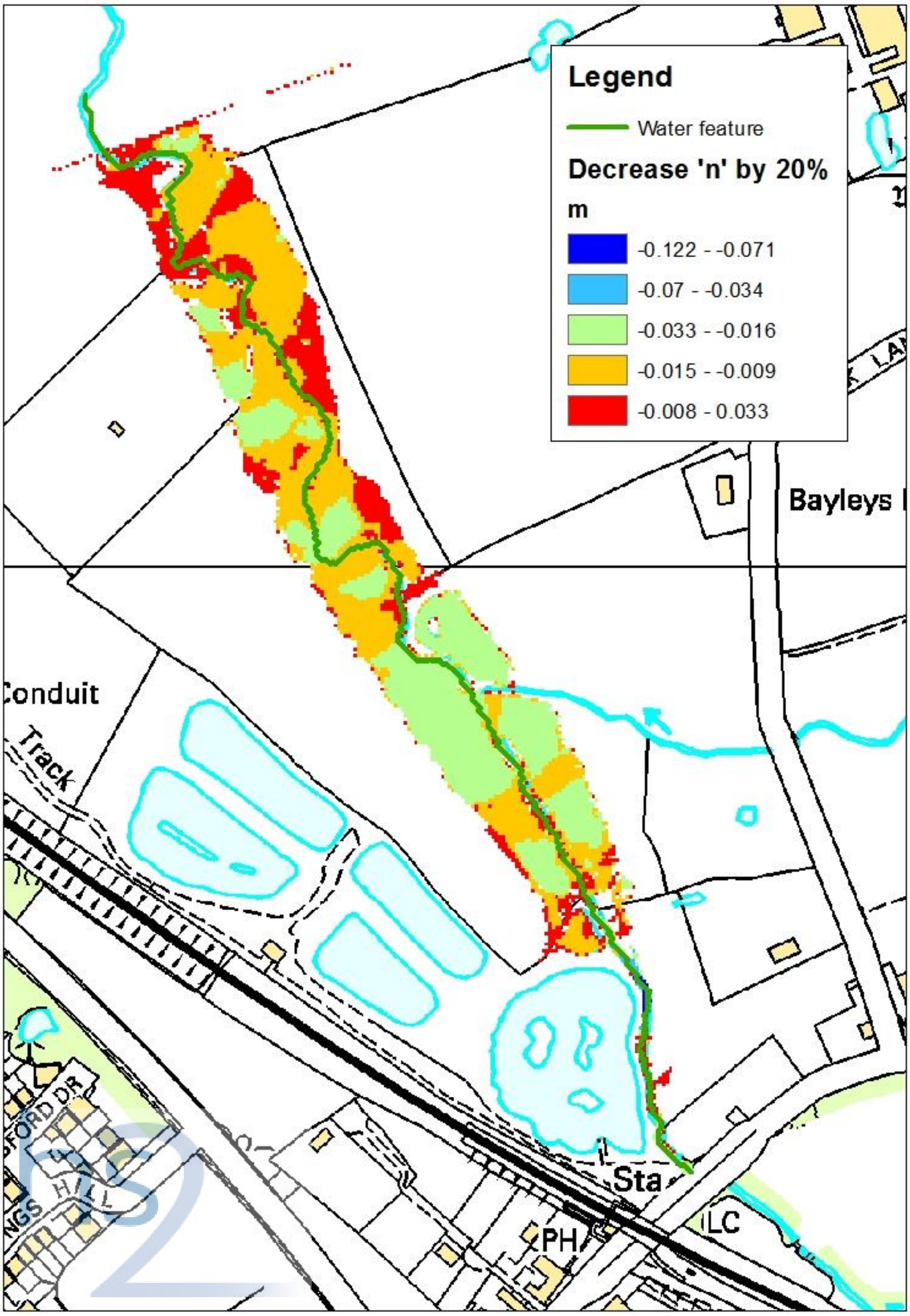


Figure 13: Change in flood extent between baseline and increasing 'n' by 20% for 1% AEP



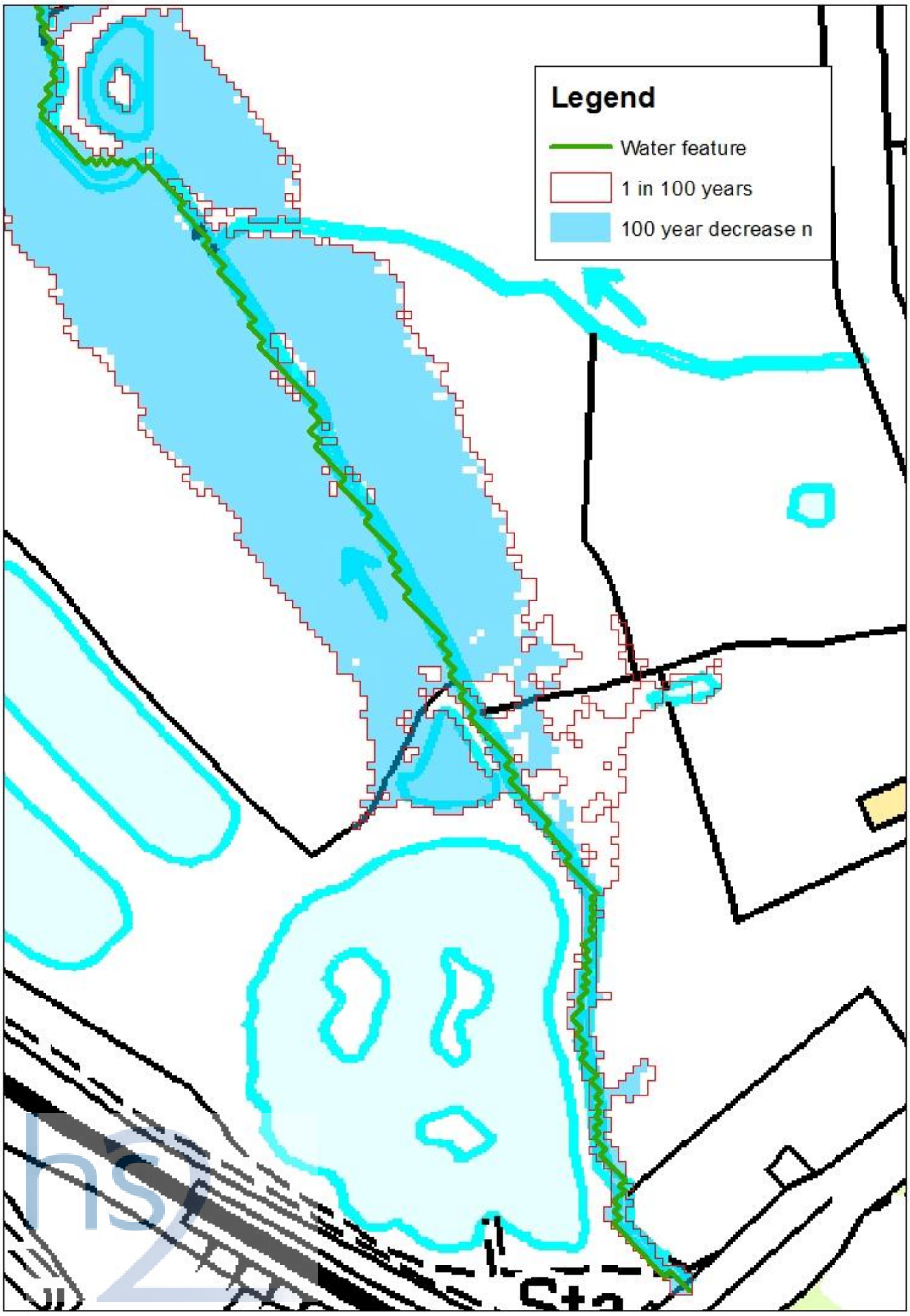
5.5.5 Decreasing Manning's roughness by 20% resulted in the typical change in baseline water level is less than ±35mm as seen in Figure 14. The maximum change of -120mm occurs at the upstream reaches of the channel just as the brook bends around the northern boundary of the pond.

Figure 14: Change in depth between baseline and decreasing 'n' by 20% for 1% AEP



5.5.6 The flood extent is reduced in the area to the north east as seen in Figure 15.

Figure 15: Change in flood extent between baseline and decreasing 'n' by 20% for 1% AEP



5.5.7 The Bayleys Brook model demonstrated that for the scenarios considered, the model results are not sensitive to roughness assumptions.

Downstream boundary condition

5.5.8 The downstream boundary sensitivity test for Bayleys Brook considered a significantly shallower slope of 0.0001 than that used in the baseline modelling (0.004). The results of the baseline modelling demonstrated the model is not sensitive to a varying boundary condition. There is a maximum change in water level of 280mm at the downstream extent of the model but this change diminishes to baseline levels within a few metres upstream of the downstream boundary.

Blockage analysis

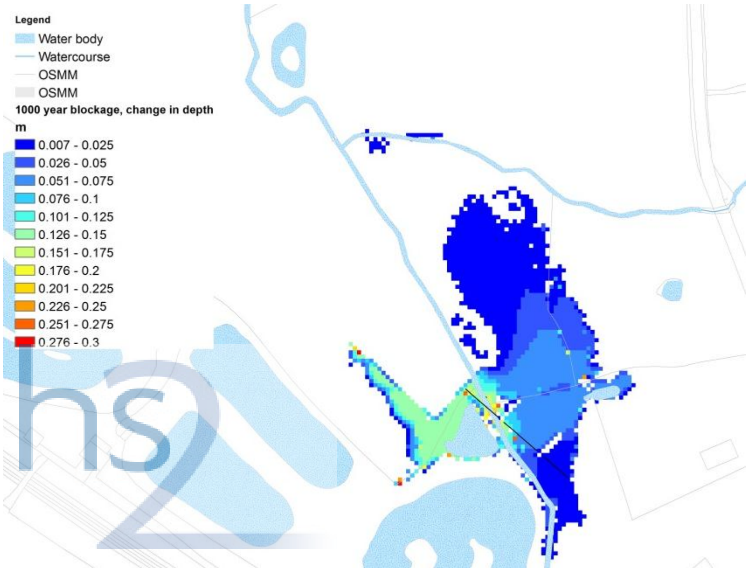
5.5.9 A blockage analysis was carried out with the following assumptions:

- blockage Balsall Common viaduct by 2%; and
- blockage of Lavender Hall culverts by 10% (facilitated by changing the downstream boundary condition to a known water level which was extracted from the Lavender Hall HEC-RAS model – see separate modelling report on HEC-RAS modelling).

5.5.10 The results show a local increase in water level at the downstream extent of the model due to the change of boundary condition to represent the 10% blockage of the Lavender Hall culverts. However, this increase in water level returns to baseline levels within 30m of the downstream boundary.

5.5.11 Typically in the vicinity of the Proposed Scheme, the increase in water level is 60mm or less when compared to the post development 0.1% AEP level. Water level increases are typically 150mm, but at localised locations levels increase by 300mm or more. At the downstream boundary (not show), there are increases of up to 1.6m but these are only at the boundary line, and within 40m no change is noted. Any increase in level does not overtop or reach the soffit of the Balsall Common viaduct.

Figure 16: Increase in water level from blockage analysis on the 0.1% AEP event



6 River Blythe

6.1 Modelling overview

6.1.1 The River Blythe has been modelled between Siden Hill Wood and Diddington Hall, with a total extension of 3.2km around the River Blythe viaduct. The model is fully 2D and is based on a regular grid with a resolution of 3m.

6.1.2 The ground elevations in the model were updated using the most recent 0.25m LiDAR DTM data, which was flown in 2012. Ground levels within the model vary between 82.1 and 93.1m aOD.

6.1.3 The model covers a total area of 105 hectares along the 3.2km reach, which extends sufficiently far to contain the flood extents of all modelled events (with return periods up to 0.1% AEP).

6.1.4 Roughness values are specified in the TUFLOW model spatially and assigned a Manning's 'n' roughness coefficient. The River Blythe floodplain had more variable roughness around the sighting of the viaduct. Therefore, the Ordnance Survey MasterMap data was used to spatially define land use in the model and roughness values were specified for each as shown in Table 1.

Table 1: Land uses and roughness coefficients

Land Use	Manning's 'n'	Land Use	Manning's 'n'
Building	0.500	Natural environment (orchards)	0.060
General surface (manmade)	0.017	Natural environment (scrub)	0.100
General surface (batural)	0.035	Natural environment (rough grassland)	0.035
Inland water	0.030	path	0.033
Natural environment (coniferous trees)	0.100	Road or track	0.016
Natural environment (non coniferous trees)	0.100	Roadside	0.033
Natural environment (marsh reeds)	0.070	Structure	0.500

6.1.5 The model applies a single flow-time boundary at the upstream end of the modelled reach. This represents flows from the entire 131km² catchment area defined at the downstream end of the modelled extent (refer to hydrological report in Volume 5: Appendix WR-004-016).

6.1.6 Inflow hydrographs were generated for a duration of 27 hours on the River Blythe which was based on the recommended value from ReFH.

6.1.7 Both models assume a 'normal depth' level-flow relationship at the downstream end of the modelled areas. This was set to 1 in 435 (0.002m/m) which is the slope over the last 100m of the modelled extent and is located 1.5km downstream of the River Blythe viaduct.

6.1.8 A channel has been defined within the 2D domain with an assumed channel depth of 0.5m and a width of 7m. Approximate depth readings were taken on site at A452 Kenilworth Road and B4102 Meriden Road with readings of between 0.45m and 0.75m depth. The A452 Kenilworth Road and B4102 Meriden Road were represented in the model by using flow constriction cells, and a blockage factor to represent the effect of the arches and piers. There is a flood relief culvert under Kenilworth Road but this has been omitted from the model at this present time. The A452 Kenilworth Road is a split dual-carriage way, with a dual arch bridge on the upstream side and a larger rectangular bridge on the downstream side. A range of model representations and assumptions have been tested for these bridges to understand the impact on the Proposed Scheme. It has been found that changing the representation results in water level changes of ~200mm. A conservative approach has been adopted, but it is recommended that the representation of this structure is reviewed during further stages of work.

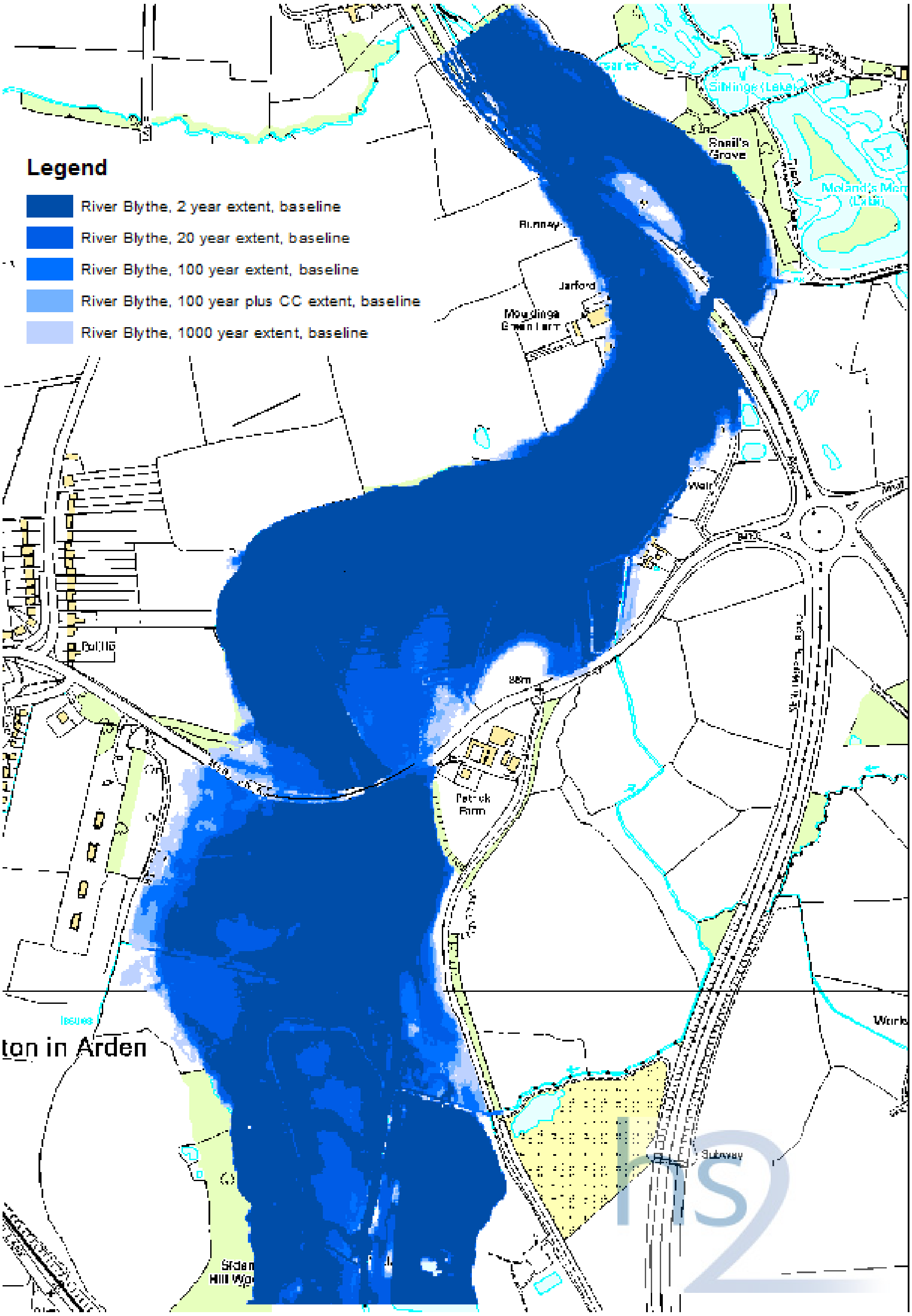
6.1.9 The recommended/default values of runtime parameters were used in all model simulations. A time step of 1.0s was used in the model simulations, which is appropriate for a 3m resolution model with good stability.

6.1.10 Mass balance checks were undertaken to ensure the models adequately conserve volume, i.e. do not gain or lose large volumes of water during model simulations. Mass errors are all below the typical threshold of 1%, indicating healthy/stable model. In the initial few minutes of the model, higher mass errors are observed, but these do not occur near the peak of the simulation.

6.2 Baseline model results

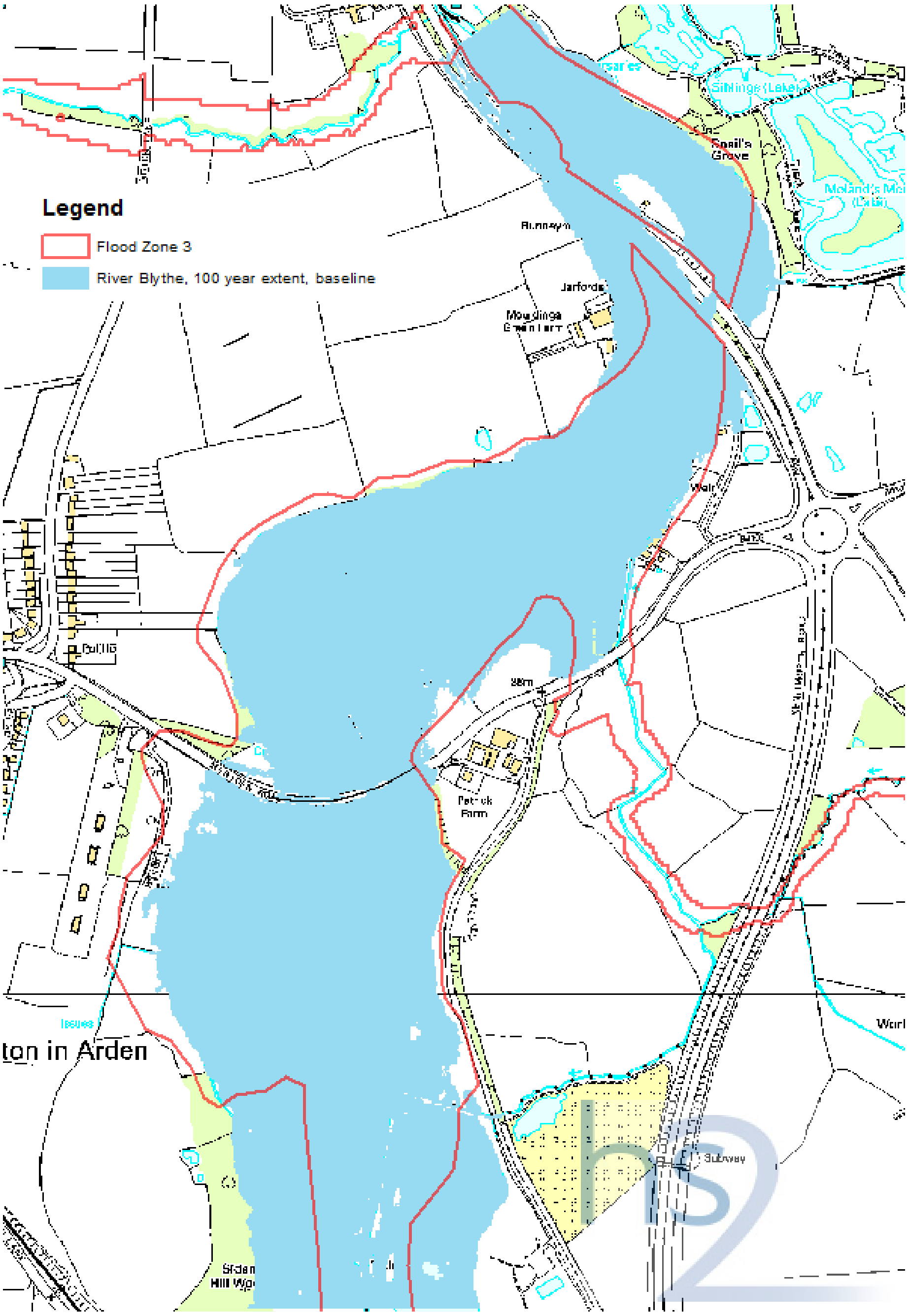
6.2.1 The baseline flood extents for key return periods are shown in Figure 17.

Figure 17: Flood extents (River Blythe baseline model)



6.2.2 From Figure 17, it can be seen that there is extensive overland flow at relatively low return periods. At the location of the River Blythe viaduct, there is overtopping of the B4102Meriden Road, but Patrick Farm currently does not experience any flooding even at extreme events. The model results for the 1% AEP show a reasonable comparison to flood zone 3, with a localised change in flood extent shown in Figure 18.

Figure 18: Changes to 1% (with climate change) peak water level (River Blythe post-development model – NB no change or decreases not shown)



6.3 Post-development model

6.3.1 A post-development scenario model has been developed from the baseline model to reflect the Proposed Scheme. This includes a six span viaduct. There will be embankment on the eastern floodplain, Patrick embankment.

6.3.2 The post-development model was used to simulate the range of return periods detailed in Section 0. Results for the River Blythe post-development model are summarised in the following table and figures.

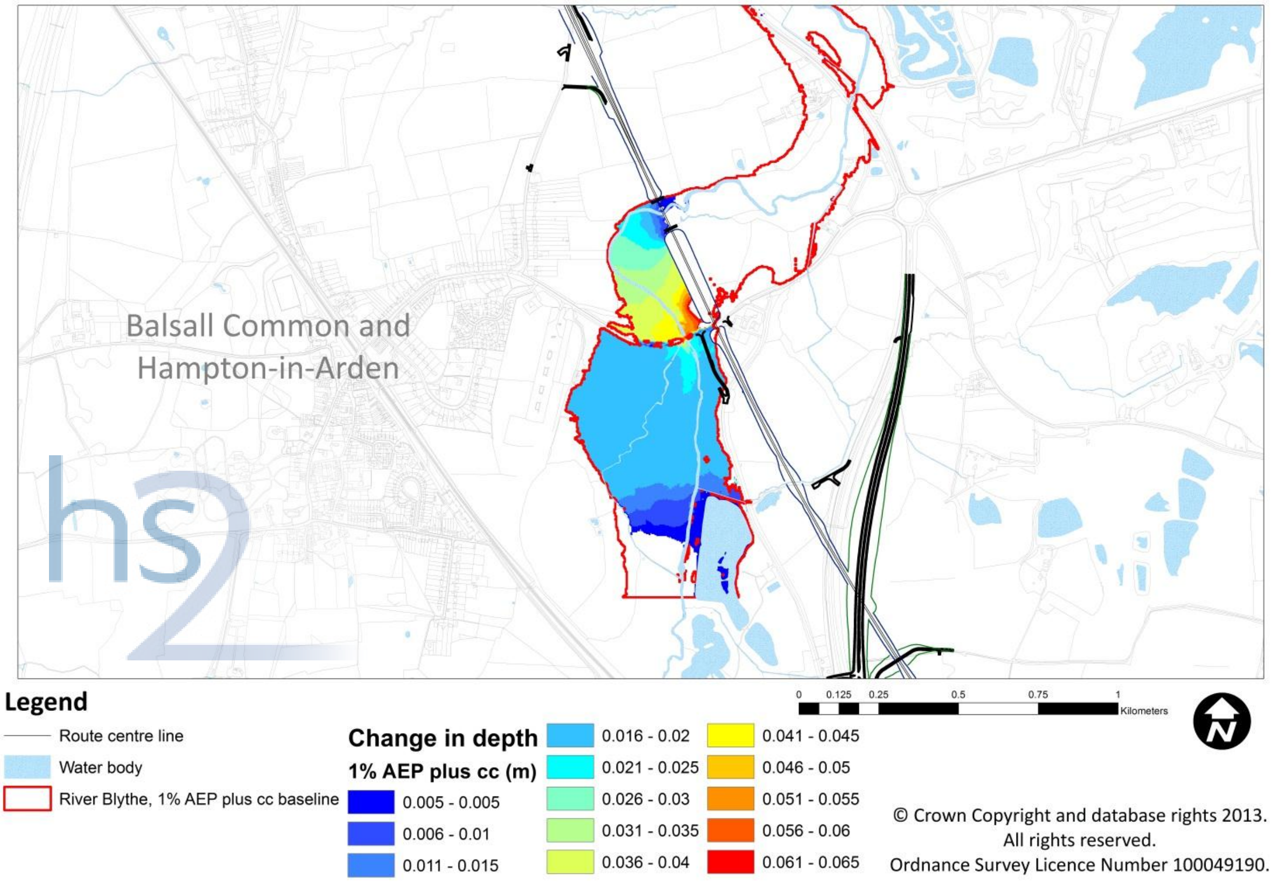
6.3.3 As shown, maximum increases in peak water levels along the river centreline, due to the Proposed Scheme, range between 0.006m (50% AEP) to 0.036m (1% AEP + climate change). Within the floodplain, differences of up to 0.6m can be observed, but this is due to a change of flood extent over one or two cells in isolated locations, and typical change in depths across the floodplain for the 1% AEP plus climate change event is less than 50mm. The increase in water levels within the floodplain and main channel at the 1% AEP plus climate change event can be observed 600m upstream of Meriden Road (depth increases of ~30mm) with water levels returning to baseline levels.

6.3.4 When considering changes to peak flows, results show that the small changes (<±0.1%) at the Proposed Scheme and at A452 Kenilworth Road are negligible (<±0.1%).

Table 2: Summary of results (River Blythe post development model)

Simulation, AEP	**Maximum change**		
	Peak water level (m)	**Peak flow (m^3/s)**	
		Kenilworth Road	**River Blythe viaduct**
50%	0.006	0.022	0.017
10%	0.012	0.024	0.020
5%	0.016	-0.019	-0.014
2%	0.022	0.005	0.005
1.33%	0.025	-0.014	-0.003
1%	0.028	0.016	0.014
1%+ CC	0.036	0.007	0.047

Figure 19: Changes to 1% (with climate change) peak water level (River Blythe post-development model – NB no change or decreases not shown)



6.3.5 Effect on B4102 Meriden Road: Meriden Road, under current modelling assumptions, indicates that flood levels will increase adjacent to the route for flood events equal to and greater than the 5% AEP event. Increases of up to 60mm are observed for events up to and including the 1% AEP plus climate change event. There are also small increases in flood extent on the road. Downstream of the Proposed Scheme there is either no change or a decrease in flood levels in the post development case.

6.3.6 Effect at A452 Kenilworth Road: model results show that Kenilworth Road bridge acts as a constriction on flows during flood events. Indicative opening dimensions were taken during a site visit and have been used to inform its representation in the model. However, it would be prudent to further assess its impact, and consider linking to the model to a 1D hydraulic modelling package such as ISIS to allow for better definition of the arches and piers when detailed survey is available.

6.4 Sensitivity testing

Overview

6.4.1 Given the absence of calibration data, surveyed flood levels or historic flood outlines for the modelled reaches of the River Blythe, a range of sensitivity tests were undertaken for the most critical assumptions within the baseline model. These are:

- roughness coefficients; and
- downstream boundary condition.

6.4.2 These were carried out for the 1% AEP event.

6.4.3 Blockage analysis was carried out on the 0.1% AEP assuming the viaduct was 2% blocked.

Roughness coefficients (sensitivity tests 1 and 2)

6.4.4 The baseline models' sensitivity to roughness coefficients was assessed by considering ±20% variations on the adopted Manning's 'n' roughness values for an earlier version of the model. The differences between this model and the previous version included updates to the representation of B4102 Meriden Road and A452 Kenilworth Road bridges, and minor changes were made to the hydrology/boundary conditions. As none of the changes affected the roughness parameters used, the roughness sensitivity test was not repeated. The results from the previous work are summarised below.

6.4.5 Sensitivity test 1 considers a 20% increase in Manning's 'n' values. As expected these changes to roughness coefficients result in higher peak water levels across the modelled reach, with an average increase in peak water level of 0.04m and a maximum increase of 0.93m. This significant increase in water level occurs upstream of the weir adjacent to Siden Hill Wood and is over a small, localised area in the upper extent of the model. Downstream of Kenilworth, peak water levels increase by up to 0.1m, but this does not transfer upstream through the bridge at Kenilworth Road.

6.4.6 Sensitivity test 2 considers a 20% decrease in Manning's 'n' values. As expected these changes to roughness coefficients result in lower water levels along the modelled reach, with an average decrease in peak water level of 0.04m and a maximum decrease of 0.89m, which is again in a localised area.

6.4.7 Results show the baseline model is relatively insensitive to roughness coefficients, except in isolated locations. However, in the absence of accurate calibration data, the proposed coefficients – established based OS MasterMap data and site walkthroughs and in line with recommended values – are deemed the most credible representation of the existing river system.

6.4.8 An additional sensitivity to roughness coefficients was assessed for the baseline model (sensitivity test 3) and post-development model (sensitivity test 4) by considering a minimum out-of-bank Manning's 'n' value of 0.050 (compared to a typical value of 0.035 in the baseline model). Results for sensitivity tests 3 and 4 are summarised in the following figures.

6.4.9 As expected, the changes to roughness coefficients in sensitivity test 3 result in marginally higher peak water levels across the modelled reach, except in a few isolated location where the maximum level increase over the baseline is 1.12m (compared with 0.89m in sensitivity test 2).

6.4.10 The changes to roughness coefficients in sensitivity Test 4 also result in marginally higher peak water levels across the modelled reach, with the average and peak increases being the same as sensitivity test 3.

6.4.11 Results show both baseline and post-development models are similarly sensitive to roughness coefficients. Once again, in the absence of accurate calibration data, the proposed coefficients, established based OS MasterMap data and site walkthroughs and in line with recommended values, are deemed the most credible representation of the existing river system.

Downstream boundary condition (sensitivity tests 5 and 6)

6.4.12 As the boundary conditions both upstream and downstream had been amended, these sensitivity tests were re-run with a ±20% change in the normal depth slope used. The baseline model uses a slope of 0.0023m/m which was measured over the last 100m of model extent. The sensitivity runs includes slopes of 0.0019 and 0.0028 for tests 5 and 6 respectively. Results for sensitivity tests 5 and 6 are summarised in Figure 20 and Figure 21.

6.4.13 Sensitivity Test 5 considers a 'normal depth' slope of 0.0019. As expected, this change to the downstream boundary condition results in higher peak water levels. Large increases to peak water levels (>100mm) are confined to the 50m immediately upstream the model's boundary and have a maximum value of 0.275m. The increase in water levels is noticeable up to the boundary of Kenilworth Road, but the increases are typically less than 10mm.

6.4.14 Sensitivity test 6 considers a 'normal depth' slope of 0.028. As expected, this change to the downstream boundary condition results in slightly lower peak water levels. This is observed over the bottom reach of the model up to the A452 Kenilworth Road structure, but the change is small, ranging from 0.05m immediately adjacent to the boundary, to <10mm up to A452 Kenilworth Road.

6.4.15 Results show the River Blythe baseline model has limited sensitivity to the downstream boundary condition, with changes largely confined to the lower reaches of the model. There are a few local changes in flood depths at B4102 Meriden Road, and some drains in the upper reaches, but these differences are small and very localised (a few cells). These will not impact on the solutions at the route crossing location.

Figure 20: Changes to 1% AEP (without climate change) peak water levels (River Blythe sensitivity test 5)

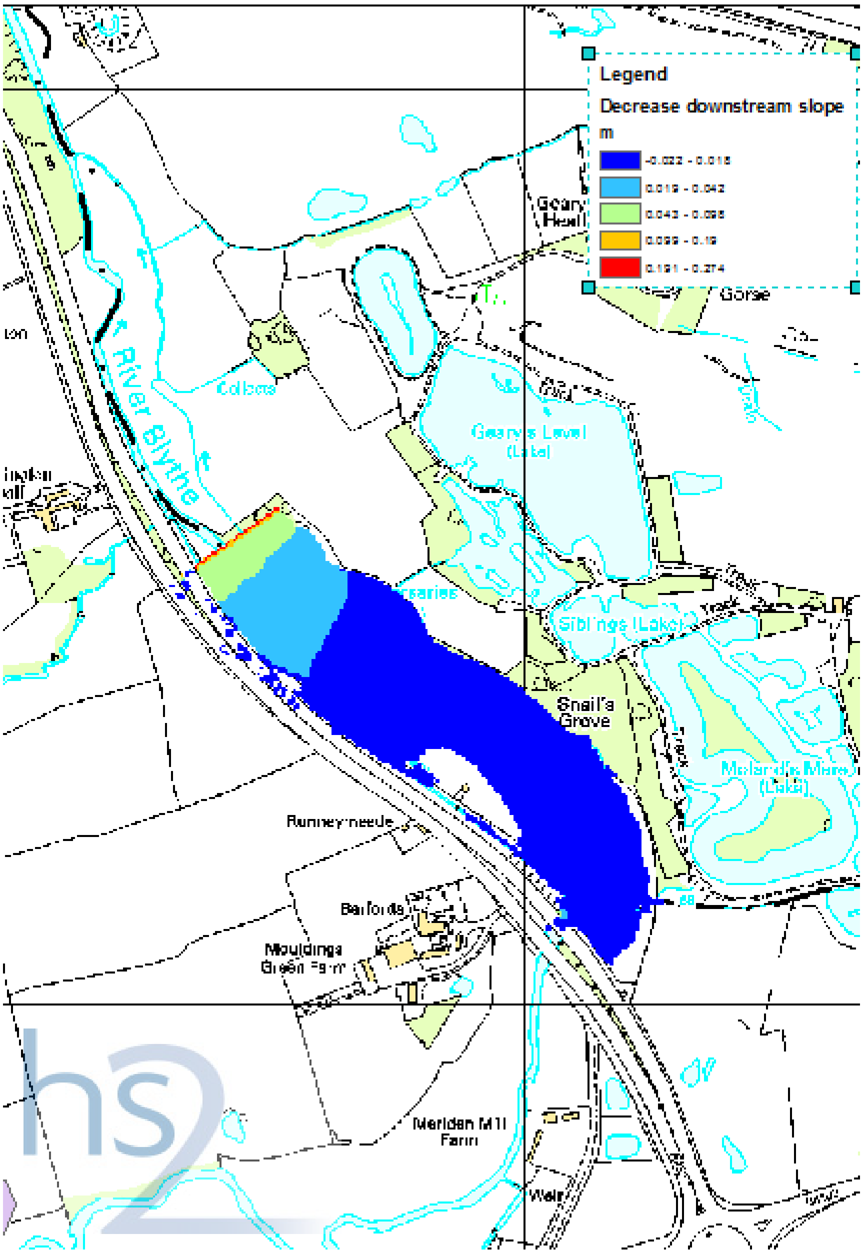
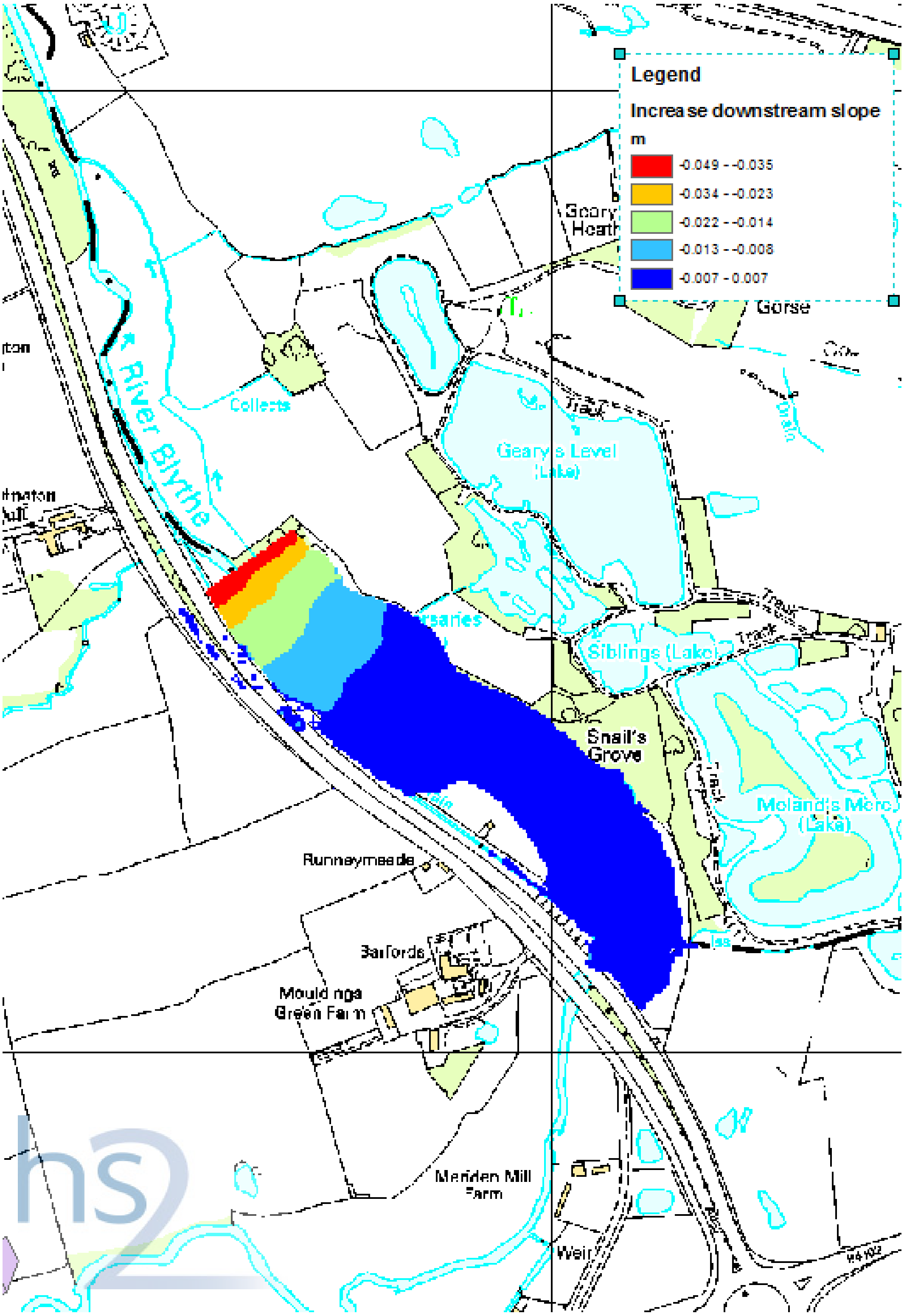


Figure 21: Changes to 1% AEP (without climate change) peak water levels (River Blythe sensitivity test 6)



Blockage of structures (sensitivity tests 7)

6.4.16 The model's sensitivity to blockage of structures was assessed at proposed structure 1542 (blocked by 2%) and B4102 Meriden Road and A452 Kenilworth Road bridges, each blocked by 10%.

6.4.17 Blocking the Proposed Scheme viaduct results in a negligible (<0.01m) impact on estimated peak water levels.

6.4.18 Blocking the A452 Kenilworth Road bridge results in a significant increase to peak water levels between A452 Kenilworth Road (~0.25m increase) and B4102 Meriden Road (~0.01m increase). At the proposed route, the maximum increase to peak water levels is ~0.10m.

7 Conclusions and discussion

7.1.1 Hydraulic models have been developed for two watercourses that will be impacted by the current Proposed Scheme, namely the River Blythe and Bayleys Brook. These were developed to define the flood extents for the baseline situation over a range of return periods (see Volume 5: Appendix WR-004-016). These models were further developed to include the Proposed Scheme infrastructure and assess any impact on flood risk. From the results of this modelling, it has been established that the Proposed Scheme infrastructure marginally increases flood depths and extents, but there is no impact to property. There is a larger impact on both watercourses where water is ponding against the embankment walls. However, the effects are still localised with little to no change to the flood extents. Although there are only localised changes between baseline and post-development, provision for partial replacement floodplain storage has been made based on the 1% AEP plus climate change levels, but has not been included within the hydraulic modelling.

8 Limitations

8.1.1 These models have been developed with the purpose of understanding flood risk within a limited reach of the watercourse and have not been designed to provide a catchment wide analysis. They have been developed solely to support Volume 5: Appendix WR-003-023. The models have been created using detailed LiDAR to pick up main topographical features in the floodplain. Where existing structures have been included, no detailed topographical survey has been undertaken and therefore sizing assumptions have been made. The channel has not been well represented due to complete lack of survey data for the channel or existing structures. In both models, the representation has been improved by defining the channels spatial location and approximate depth.

8.1.2 It is therefore recommended that during further stages of this project, additional survey is obtained of key structures and internal channel dimensions and further refinement of the hydraulic models undertaken.

9 References

Environment Agency, (2012), Flood zone mapping GIS layer.

Environment Agency, (2012), Midlands Historical 1992 and 2007 flood event GIS layers.